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RESEARCH ARTICLE

A Multi-Frequency Replication of the MegaREG Experiments

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Abstract—The MegaREG set of experiments run by the Princeton Engineering Anomalies Research (PEAR) group prior to 2004 found that the response to human intention was positive when the Random Event Generator (REG) bit-rate was 200 bits per trial, but increased in magnitude and was negative in direction when the bit-rate was 2 million bits per trial. This reversal of the influence could not be explained within the existing theories of psi influence, and for several reasons this avenue of investigation was terminated. Given that this effect might represent a clue to the underlying structure of mind–matter influence, the current study set about replicating and extending the MegaREG experiments by examining the influence of human intention over a range of 10 different frequencies from 200 bits per second to 16 million bits per second, on a new, purpose-built REG machine. The study used commercially available REGs, covered 127 series of 1,000 trials each, and was undertaken mainly by 5 operators over a period of 18 months, following protocols similar to those of the PEAR study. The results are ambiguous with respect to the reversal of influence at a high bit-rate but appear to support the MegaREG findings of an increase in effect size with bit-rate, though below statistical significance. It is concluded that further work should address this apparent effect amplification, as any increase in effect size with bit-rate would be of undoubted value to mind–matter investigations.

Keywords: consciousness—anomalies—human–machine interaction—random event generators—replicability

Introduction

In the PEAR (Princeton Engineering Anomalies Research lab) mind–matter experiments, operators tried to “influence” random event generators (REGs). Random event generators can be set up to produce binary bits, 0s

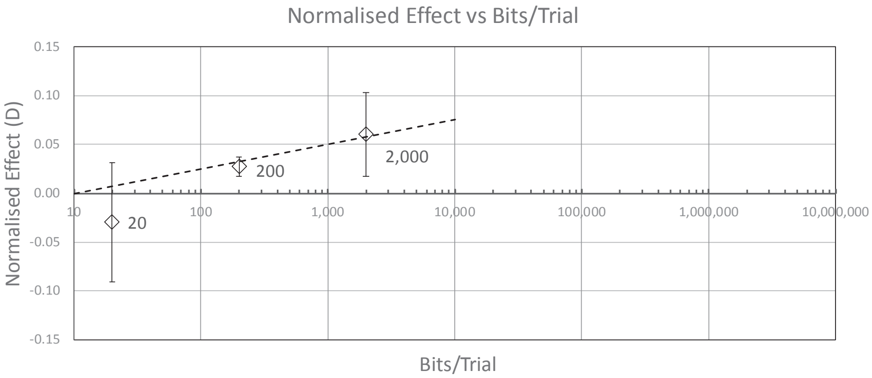

Figure 1. Pilot tests giving the suggestion of a bit-wise amplification of effect.

and 1s. The expectation from chance is that half the output will be 0s and half will be 1s. In each experimental session, the volunteer-operator first chooses and records what they want: more 0s or more 1s. They initiate the process and try to influence the REG in the chosen direction. While there are many variants, a typical session may last 15 minutes, and comprise 1,000 separate trials, each lasting about 1 second. Each 1-second trial may involve the generation of 200 bits, about one hundred 1s and one hundred zeros. The actual number is recorded and shown in a display that is updated each second, so the volunteer can see how they are doing. PEAR results show that over many thousands of trials there is a small but consistent residual effect that is in line with human intention and is not expected by chance (Dunne & Jahn 1992, Jahn et al. 1997, Jahn & Dunne 2005).

Pear's Motivation for the MegaREG Study

The postulate of what was physically happening, was that each bit was being "forced" by the mind in the direction of the operator's intention. If the force was the same for every bit, then having more bits in the process would result in a bigger effect. This idea was called the "bit-wise" effect which was anticipated by at least one author to scale as the square root of the number of bits. To test this idea, PEAR ran some pilot sessions with 20 and 2,000 bits/trial. The results are shown in Figure 1 and suggest that there indeed could be a bit-wise increase in effect.

PEAR's MegaREG Experiments

The original MegaREG experiment by a PEAR visiting scholar (Ibison 1998) attempted (among other things) a more thorough test of the bit-wise–

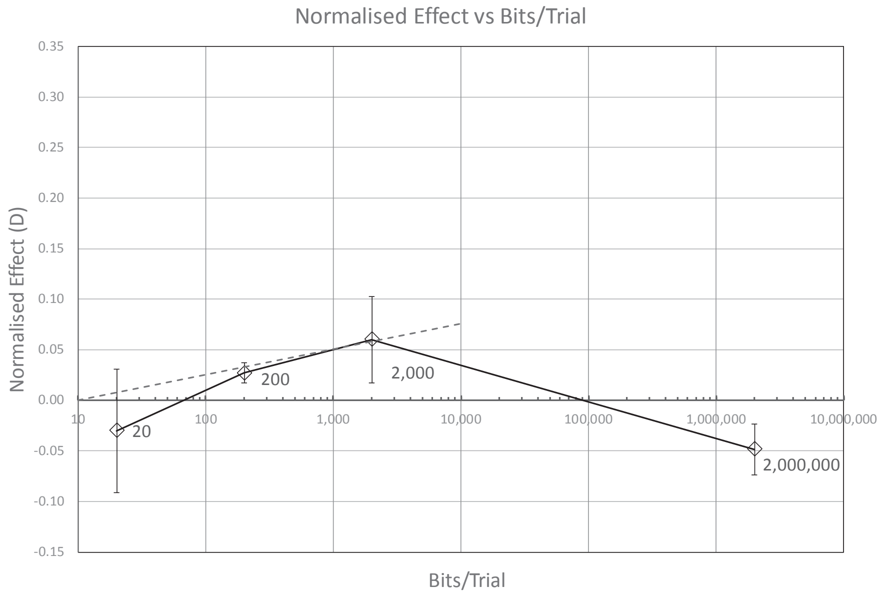

Figure 2. PEAR results for the MegaREG study.

effect hypothesis. This had the REG running at 10 MHz with the capability to source robustly random samples at 2 million bits per second. It was designed to display the results the same way as in the traditional PEAR tests at 200 bits per second. The MegaREG experiment also had the capability to source trial bits at 2 million and 200 bits per second in the same run. That is, in a given 15-minute session there might be half the trials at 2 million bits per second and half at 200 bits per second. Which of the two was presented to the operator was itself decided by a random process that was invisible to the operator. The subsequent analysis could separate any difference between the two frequencies, for the same intention. Because all bits were sourced from the 10 MHz REG, they each took the same interval of time for their production, and in the forcing model would each gather the same force (Dobyns et al. 2002, 2004).

The challenging results are shown in Figure 2 and listed below:

1. The high bit-rate (2MHz) gave results **opposite** to intention. This was unexpected.
2. The interleaved lower bit-rate (200Hz) gathered in the same runs gave results **in line** with intention (and in line with previous findings).

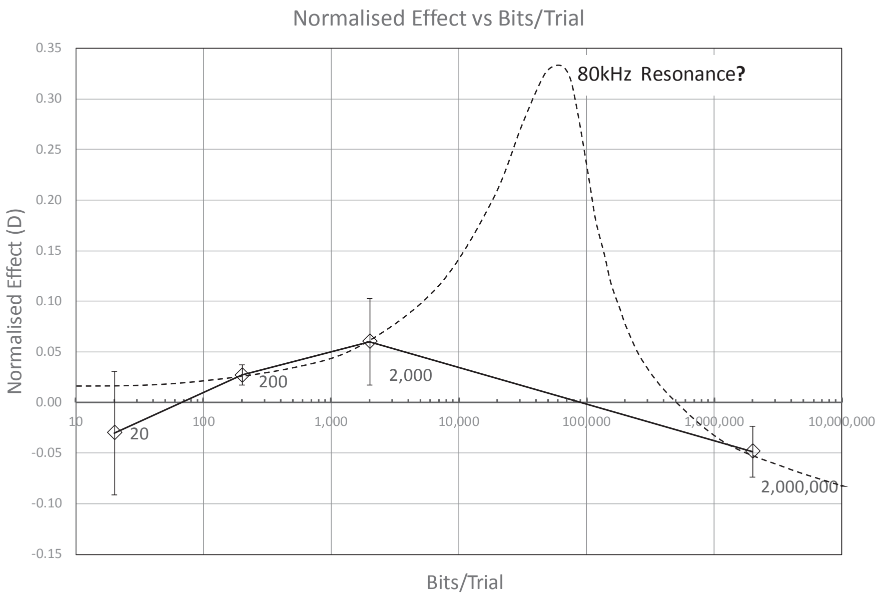

Figure 3. A possible interpretation of the MegaREG results.

3. Assuming the "forcing" model, the <u>bit-wise</u> effect size at the high bit-rate would be expected to be at least ten times that of the lower bit-rate. Instead the bit-wise effect <u>decreased</u> by 33 times.
4. On the other hand the effect size <u>per trial</u> was **larger** by 2.77 times than that of the 200 Hz bit-rate.
5. "The cause of the increase in the effect size [per trial] and inversion with respect to intention is unknown" (Dobyns et al. 2004).

Motivation for this Replication Study

The original motivation for the MegaREG experiment was to find out if a statistically significant mental influence on a random process could be achieved more quickly by gathering data at much higher rates than had been done in the past. Both Ibison and Dobyns et al. (2004) had this as a stated objective for the MegaREG experiments. The author of this replication, with the same motivation, was taken by the MegaREG results, because:

1. It was clear from the PEAR conclusion that the mechanism was still unexplained.
2. MegaREG appeared to provide evidence of some (if small) **signal amplification** per trial that was **bit-rate–dependent**.

3. The inversion anomaly suggested there might be an **optimum** bit-rate frequency somewhere.
4. In particular there could be a beneficial **resonant bit-rate** frequency with a large amplification of the effect, potentially as illustrated in Figure 3.

After visiting PEAR and discussing the MegaREG results with them, I decided to proceed with an independent replication of the MegaREG study.

Objectives of This Replication Study

1. Replicate the MegaREG experiments.
2. Test the hypothesis that the bit-wise effect is present at yet higher frequencies than 2 MHz.
3. Test the hypothesis that there is some optimum operating bit-rate.
4. Test the hypothesis that the reversal of the effect at high frequencies is a replicable result.

Quantifying Effect Size

The normal way to measure the effect in mind–matter experiments involving binary strings, is to measure the displacement δ of the trial distribution mean from the mean expected by chance. For the "Hi" and "Lo" intentions, the effect size would be represented respectively by:

$$\delta_h = \mu_h - \mu$$

$$\delta_1 = \mu - \mu_1$$

The MegaREG work used the tripolar protocol which meant that each trial involved one set of "Hi" intention, one of "Lo", and one of "BL" or baseline. This tripolar protocol was developed to guard against irregularities in the REGs of the time. But the fact that there were the two influence effects being gathered at the same time, Hi and Lo, allowed a "Figure of Merit" to be developed as follows:

$$D = \frac{\mu_h - \mu_l}{\sqrt{2}}$$

Here the difference between the Hi and Lo means $\mu_h - \mu_l$ is equivalent to the sum of the magnitudes of the two displacements of the means δ_h and δ_l, that is:

$$D = \frac{\delta_h + \delta_l}{\sqrt{2}}$$

where: D = the Figure of Merit, a measure of the size of the mental influence
μ = Mean expected by chance
μ_h = Mean of all trial results with Hi intention
μ_l = Mean of all trial results with Lo intention
δ_h = Mean shift from chance expectation, in the "Hi" direction
δ_l = Mean shift from chance expectation, in the "Lo" direction

Assuming the displacement of the mean was equal in size and opposite in direction for the Hi and Lo cases, then D is twice the effect size in one direction only.

Figure of Merit for This Replication Study

In this replication study, the tripolar protocol was not used. Operators could choose their direction of intention and some operators adhered to a single direction throughout all their trials. The output in this study was only recorded as positive in the direction of intention and negative in the direction opposite to intention. The result is a mean shift that is half the size of the MegaREG "Figure of Merit." To be on the same footing as the MegaREG study, the replication study mean shift, d_R, was doubled to get an equivalent figure of merit size for comparison.

Taking into account the square root of 2 in the MegaREG figure of merit, the equivalent figure of merit in the current replication study is:

$$D_R = \sqrt{2}\,\delta_R$$

where: D_R = Normalized Figure of Merit for the Replication Study
δ_R = Mean of a set of trial distributions in the direction of intention

Normalizing the Effect at Different Bit-Rates

Since different bit-rate frequencies will result in different mean sizes, the MegaREG results were "normalized" so that the mean trial output at any bit-rate would be represented in the same way as the output from the 200 bits/second standard tests used by PEAR. The normalization extended to adjusting all standard deviations and measurement uncertainties to a common size for direct comparison. This allowed the effect size per trial to be readily compared across all bit-rate frequencies. The normalization equation for trial means is:
Normalized Mean

Figure 4. The REG source for the replication machine.

$$\mu_N = \left(\sqrt{\frac{BPT_{ref}}{BPT}} \right) \times (\mu_{BPT} - 0.5 \times BPT) + 0.5 \times BPT_{ref}$$

where:

μ_{BPT} = Mean of trial score distribution at a second bit-rate
μ_N = Normalized mean trial score distribution for the second bit-rate
BPT = Bits per Trial at the second bit-rate
BPT_{ref} = Bits per Trial for the reference bit-rate (in this case BPT_{ref} = 200 bits/trial)

REG and Interface Specifications for the Replication Study

The REG for the replication machine comprises 4 × Quantis, 4-MHz, certified, quantum random number generator units combined on a single board as in Figure 4, interfaced with a specially made board in a dedicated computer. For the tests described here, the 4 Quantis units ran in parallel (on "Sample Rate" setting 16 MHz in Figure 5), generating essentially a 16-million–bit array every second (and every trial), which was then sampled at regular intervals to deliver the chosen bit-rate. So for example if the chosen bit-rate was 200 bits/sec, only every 80,000th bit would be selected for the sum.

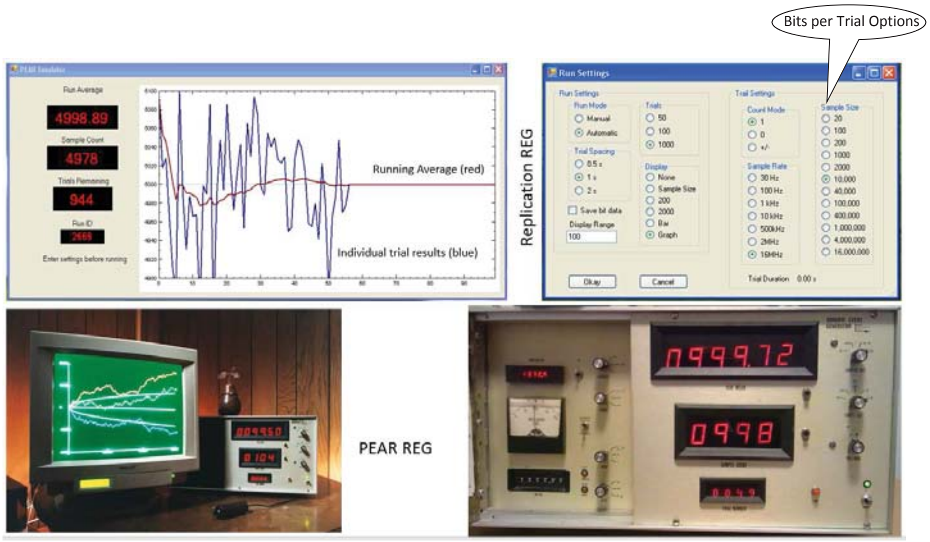

Figure 5. The replication machine interface above and the original REG machine at PEAR.

Efforts were made to reproduce the main functions of the Princeton machine with parallel functions on the replication machine. Table 1 compares the functions of both machines and their setting options. The difference of note is that while the PEAR machine has 4 bit-rate options from 20 Hz to 2 MHz, the replication machine has 12 bit-rate options (or "Sample Size" options in Figure 5) from 20 Hz to 16 MHz. This facilitates the search for any optimum bit-rate frequency between 20 Hz and 16 MHz. Figure 5 shows what the machines look like and how their interfaces compare. As can be seen, the replication machine displays both a two-part graphical representation (cumulative deviation and by-trial deviation), as well as a digital score to the left of the graphical screen.

Experimental Protocols

While PEAR used a tripolar protocol, this was largely to deal with the vulnerability of their machines to a systematic bias. Although that was appropriate at that time, the quality of available REG machines has improved since then, and the Quantis machines in particular have proven reliable in both commercial quantum cryptography (id Quantique 2018), the full battery of Die-Hard tests, and in other mind–matter experiments (Radin 2006). For these reasons it was decided in this replication to put a level of trust in the machine, and to reduce the amount of operator effort to

TABLE 1

Functions of the Princeton REG Machines Compared with the Replication Machine

	FUNCTIONS	PRINCETON REG MACHINE(S)						MegaREG	CANTERBURY REPLICATION MACHINE					
		Signals & Controls	Settings Options (Red is default)						Signals & Controls	(Red is default)				
1	Trial Mode (User starts every trial or automatic start)	Knob	Man	Auto					Click in Setup Window	Man	Auto			
2	Sampling Rate (Hz)	Knob	10	100	1k	10k			Click in Setup Window	30	100	1k	10k	500k
3	Sample Size (Bits)	Knob	20	100	200	1k	2k	2M	Click in Setup Window	20	100	200	1k	2k
4	Calibrate	Knob	1	0	+/-				(Same as Trial)	1	0	+/-		
5	No of Trials per Run	Knob	50	100	1000			[illegible]	Click in Setup Window	50	100	1000		
6	Count what?	Knob	1	0	+/-				Click in Setup Window	1	0	+/-		
7	Source	Knob	REG	Ext	Test				N/A. Only one source					
8	Start Run or Trial (depending on Man/Auto)	Button (Start, Red)	Press						Click in Run Window					
9	Trial Counter (Reset? Hide?)	Button (black)							Automatic On					
10	Reset Run Mean (Reset? Hide?)	Button (black)							Automatic On					
11	Trial Number	Display							Run Window					
12	Present Trial "Sample Count" of +,- or +/-	Display							Run Window					
13	Run Mean	Display							Run Window					
14	Temperature (for REG noise source stability)	Display												
15	Bar Graph Option	Display							Run Window					
16	Real time Graphical trial scores & Cumulative Run Score	Display							Run Window					
17	Trial duration (s)	Display							Run Window					
18	Power on/off	Switch	On	Off										
19	Farenheit/ Centigrade	Switch	F	C										
20	Meter Switch	Switch	Volt	Amp										
21	Power on/off	Light (Green)	On	Off										
22	Error Voltage	Light (Orange)	On	Off										
23	Error Count	Light (Orange)	On	Off					Trial aborts on Error					
24	Set at expected Mean for this Run (Called "Initial")	Manual set Counter												
25	Voltage or Current	Meter												
26	External Source input								Custom Card					
27	REG	Thermal Noise source							4 off certified 4MHz QRNG units ex Quantic; in 16MHz configuration					
28	Memory of Trial Summary	Automatically recorded							Always recorded automatically					

get results compared with the tri-polar protocol. For the same reason, there was no modification, or "XORing" of the certified bit-stream to deal with potential systematic bias. The possibility of systematic bias was checked at the end of the series by making use of the calibration runs data collected at the end of each volunteer session.

In another departure from the PEAR protocols, operators in this replication could opt for a Hi or Lo target for any run, and were not constrained to have balanced portions.

Other processes for the operators were largely similar to those of PEAR. Operators recorded their intention before each run ("Hi" or "Lo"), and recorded which of the 12 available bit-rate frequencies they wanted to use. They worked for about 1 hour, doing three or four 1,000-trial runs. Typically they would do no more than one session per week.

Regular calibration runs were initiated by the operators each time they finished a session and left the room where the REG was situated.

Anatomy of the Replication Dataset

The replication study comprised 127,000 trials over 18 months, with runs primarily of 1,000 trials each. They covered 10 different bit-rate frequencies from 200 bits/trial to 16 million bits/trial. There were 13 operators in all, with 5 people with more than 10,000 trials each. There were 7 females, 4 males, including 2 paired sets of volunteers among the group.

Experimental Results

Results have been presented in Figures 6 and 7 as normalized effect size D_R on the vertical axis, so that they are directly comparable to the MegaREG results in Figures 1 to 3. It quickly became apparent that the only appropriate horizontal axis was a log scale, and this has been used on all figures including Figures 1 to 3.

In line with the MegaREG study, the error bars in the figures represent a 1 SD, standard error. To represent statistical significance at $p = 0.05$, these error bars would need to be 1.96 times larger. With this in mind it is easy to read off the figures which data points are statistically significant at better than the $p = 0.05$ level. For example in Figure 6, only two data points are significantly different from no effect at all, and these are at bit-rates of 1,000,000 bits/trial ($p = 0.04$) and 16,000,000 bits/trial ($p = 0.004$).

Combined results of all operators are shown in Figure 6, and individual operator results are shown in Figure 7.

Systematic bias in the random number source was investigated by analyzing the calibration runs collected when no one was near the machine

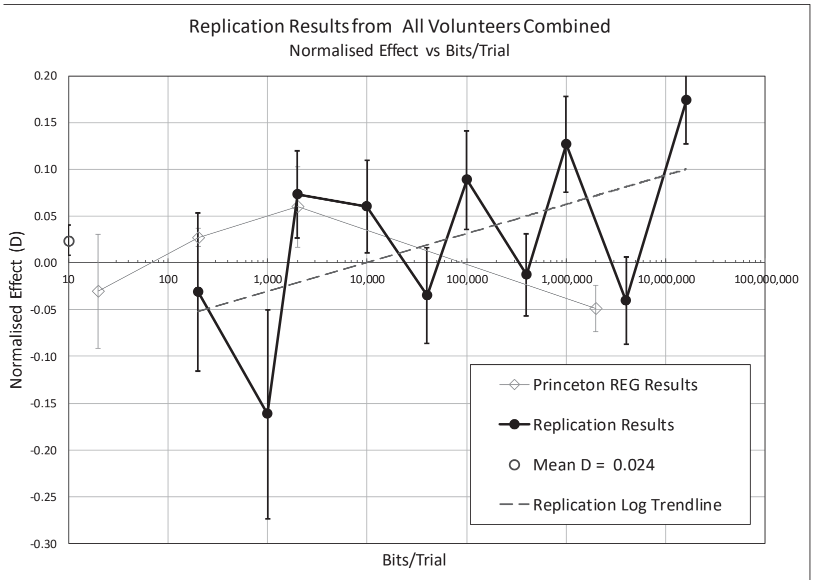

Figure 6. Results from all volunteers combined, overlaid on the MegaREG results.

or trying to influence it. The results in Table 2 show all bit-rate calibration runs, as well as the combined calibration runs.

Discussion

This study covered 10 different bit-rates rather than the two in the MegaREG study. As a result it was not realistic to run a program of tests long enough to get statistical significance at each bit-rate or for each operator. Consequently, the results, while still indicative, mostly do not have the authority of full statistical significance. This study therefore should be seen more in the nature of a pilot study that needs a follow-up study for confirmation.

Bit-Wise Effect

One of the objectives of the MegaREG experiments was to determine whether or not there was an increase in the effect of intention with bit-rate frequency, or a "bit-wise effect." The most prominent feature in Figures 6 and 7 of this replication study is an overall <u>increase in size of the intention effect with bit-rate</u> up to 16 MHz. While this is in line with the MegaREG experimental findings, the increase with bit-rate per se of this replication study is not confirmed at a significant level:

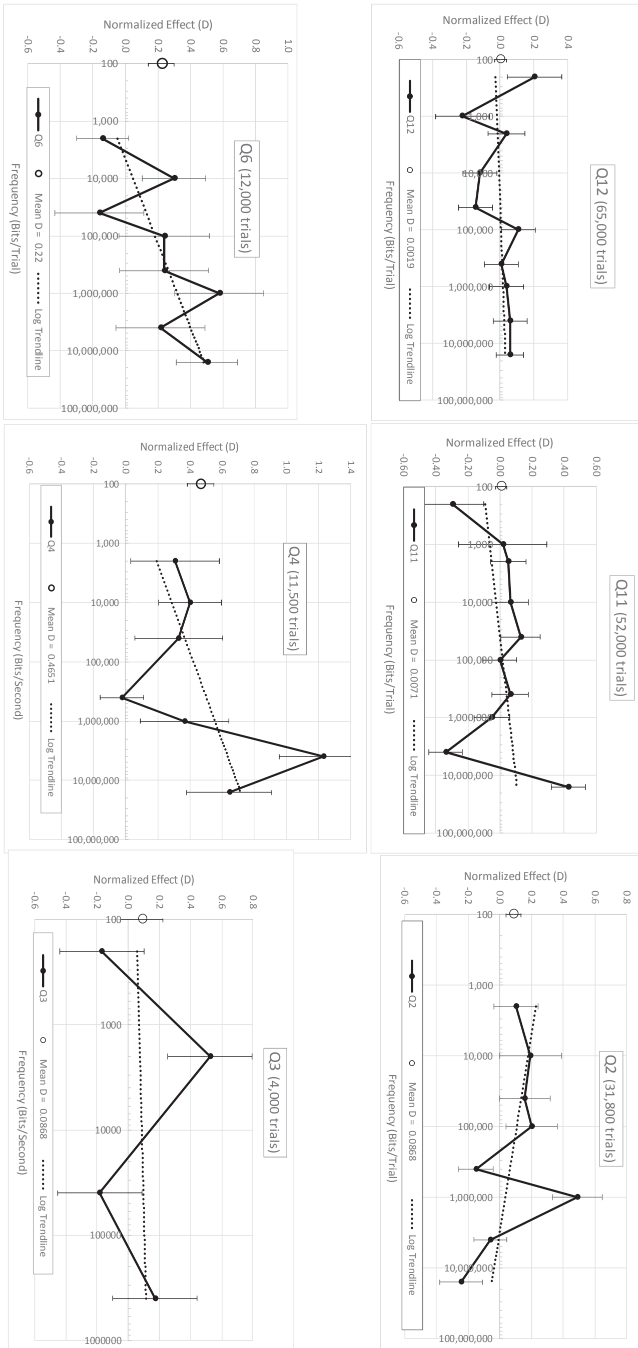

Figure 7. Results from individual volunteers who contributed 4,000 trials or more.

TABLE 2
Analysis of Calibration Runs

Bit-Rate (per sec)	200	1,000	2,000	10,000	40,000	100,000	400,000	1,000,000	4,000,000	16,000,000	Combined
No of Calibration Trials	16000	12000	9000	10000	10000	13000	81000	11000	23000	26000	211,000
Z	1.19	−0.90	−0.71	−0.01	−0.59	0.32	1.11	−0.41	0.95	−0.84	−0.39
p	0.116	0.817	0.762	0.503	0.722	0.374	0.134	0.658	0.172	0.799	0.651

- In Figure 6 the probability that the slope is greater than zero is $p = 0.3$.
- In Figure 7 the probability that the slope is greater than zero is $p = 0.09$, based on 5 out of 6 trendlines showing the increase.

Taking this as a pilot study, it is enough to inspire further work, given that it suggests a way to amplify effect size.

Signal Strength of Bit-Wise Effect

The MegaREG study, as reported in Dobyns et al. (2004), calculated that the effect size at 2 million bits per trial was 2.77 times the effect at 200 bits per trial. This amounted to an effect size of about −0.05. For the replication study the magnitude of the effect at 2 MHz shown by the trendline in Figure 6 is about +0.06. Nevertheless, until statistically significant results can be achieved this is largely speculative.

Intention-Effect Reversal with Bit-Rate

An issue that was confounding for the MegaREG experimenters, as reported in Dobyns et al. (2004), was the reversal of the effect at the 2 MHz bit-rate, the highest bit-rate of their tests. It would have been ideal if this replication study had shown that in all probability this reversal was a software error, or, on the other hand, that it was part of a replicable trend. Unfortunately, it did neither. Instead it gave two opposing indications, neither with adequate statistical significance:

1. The overall trendline in Figure 6 suggests a steady increase in effect size right up to 16 MHz, well beyond the 2 million, maximum bit-rate of the MegaREG tests. This would seem to challenge the reversal in effect in the MegaREG experiments.

2. The combined operator bit-rate results in Figure 6 show that the nearest point to the MegaREG 2 MHz point, (being at 4 MHz), is a similarly negative result, albeit without statistical significance. This could mean that there is a local minimum around the 2 to 4 MHz region that cannot be confirmed with the relatively low precision of this replication study.

These conflicting points leave unanswered the question of whether the reversal of the effect at 2 MHz in the MegaREG experiments has been replicated or not. Again, taking the replication as a pilot study, this reversal issue is worth exploring further with a more focused study.

Presence of an Optimum Bit-Rate?

In Figure 6, of the combined results of all operators there is subjectively no obvious indication of an "Optimum" or "Resonant Frequency bit-rate" peak that looks like the dotted addition in Figure 3.

Similarly in Figure 7, of the individual operator results there is no clear indication of an "Optimum" or "Resonant Frequency bit-rate." If there had been, it would appear as an increased effect across all participants at one particular bit-rate, but this is not the case.

These results give no indication that there is any value in putting more effort into looking for an optimum within this bit-rate range.

Experimenter Effect

The potential for experimenter influence needs to be addressed. It is known that the attitudes and beliefs of the experimenters themselves as well as of the operators may affect the magnitude and/or direction of the results (Kennedy & Taddonio 1976, and others). Ideally, experimenter expectations, like conflicts of interest, should be declared before starting the experiment. Although it was not done for this replication, it is still worth noting after the fact as follows.

The main hope of the author, who was the lead experimenter but not an operator, was to discover that there is an increase in effect-size with bit-rate. To a lesser degree, the author's hope was that the negative effect at high bit-rate in the MegaREG experiments would turn out to be an artefact such as a software error. The possibility of an optimum was of lesser interest.

While the author's hope for an increase in effect size with bit-rate has occurred, the reversal effect at high bit-rate in the MegaREG experiments is a bit more complicated. At this point it has not been convincingly replicated, nor convincingly denounced, by the replication study. But in the author's mind this effect reversal is nonetheless satisfactorily explained as a direction-reversing, experimenter effect, arising from the conflicting motivations of the MegaREG experimenter team that became apparent to the author, only after talking with people at PEAR. The author from the outset believed that these conflicting motivations may have been the cause of the reverse-direction results in MegaREG, through an experimenter effect generated by a passionate team in conflict.

While it remains to be seen from future work whether the effect reversal can be replicated, at this point it is notable that the replication study results align fairly well with the expectations of the lead experimenter.

Calibration and Systematic Bias

Table 2 shows that the calibration runs vary to non-significant degrees. This supports the view taken in this study that the Quantis random number generator units are not introducing a systematic bias into the results.

Recommendations and Conclusions

This study was wide but not particularly deep and should be viewed as a pilot study. It addressed three of the questions raised by the MegaREG experiments:

1. Does the intention effect increase with bit-rate at yet higher frequencies than 2 MHz?
2. Is there some optimum operating bit-rate?
3. Is the MegaREG reversal at high frequencies a replicable result?

While not having the statistical significance to be definite, the following observations may be made:

1. The indications are that the intention effect does increase with frequency, but this needs to be confirmed with a more focused study.
2. There is no evidence of an optimum bit-rate in the range investigated. This suggests there is no value in spreading future operator effort over a number of intermediate frequencies in the hope of finding an optimum as was done for this replication study.
3. This replication raises a modicum of doubt about the MegaREG reversal, but this question, too, needs a more focused study before conclusions can be drawn.

Further work should be designed to provide the statistical significance necessary to answer the single question: Does the effect of intention increase with trial bit-rate? Answering this one question with sufficient confidence will address the two remaining questions 1 and 3 above.

In conclusion, this replication has explored several issues raised by the MegaREG experiments, and has focused attention on what can be done next to settle the remaining questions. Of particular importance is the indication of a monotonic increase of effect size with bit-rate. Should future work confirm this to be the case, it will be of undoubted value to mind–matter investigations.

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